# SUPPLEMENT

## TO BRITISH TELECOMMUNICATIONS ENGINEERING

*(formerly the Supplement to The Post Office Electrical Engineers' Journal)*

**Vol. 2 Part 4 January 1984**

**ISSN 0262-4028**

## TEC & SCOTEC GUIDANCE FOR STUDENTS

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# TECHNICIAN EDUCATION COUNCIL

## Certificate Programme in Telecommuncations

Sets of model questions and answers for Technician Education Council (TEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits are shown for each question, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

### TEC: TELECOMMUNICATIONS SYSTEMS I

**TEC unit number U81/748. Students are advised to read the notes above**

***Q1*** *Indicate which one of the following statements best describes a DC voltage and which one best describes an AC voltage.*

(*a*) *Has a constant amplitude.*
(*b*) *Has a constant impedance.*
(*c*) *Has a constant frequency.*
(*d*) *Has a constant velocity.*

(*2 min*)

**A1** DC voltage—(*a*).
AC voltage—(*c*).

***Q2*** (*a*) *State the 2 main features of sound that can be detected by the human ear.*

(*b*) *For each of the features given in part* (*a*), *state one electrical property contained in an equivalent electrical wave.*

(*3 min*)

**A2** (*a*) (*i*) Loudness, and
(*ii*) pitch (or frequency).

(*b*) (*i*) Loudness is represented by the amplitude of the wave.
(*ii*) Pitch is represented by the frequency, wavelength or period of the wave.

***Q3*** *If the velocity of a wave doubles and the wavelength is halved, what is the net effect on the frequency? Does it*

(*a*) *stay the same,*
(*b*) *increase by a factor of 2,*
(*c*) *increase by a factor of 4,*
(*d*) *decrease by a factor of 2, or*
(*e*) *decrease by a factor of 4?*

(*2 min*)

**A3** (*c*) increase by a factor of 4.
[*Tutorial note:* The frequency, $f_1$, before changing the velocity and wavelength is given by

$$f_1 = \frac{\text{velocity}}{\text{wavelength}}.$$

The final frequency, $f_2$, is given by

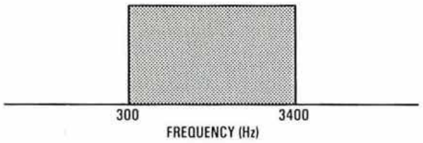
$$f_2 = \frac{2 \times \text{velocity}}{\frac{1}{2} \times \text{wavelength}},$$

$$= 4 \times \frac{\text{velocity}}{\text{wavelength}},$$

$$= 4f_1.]$$

***Q4*** *Draw and label a frequency spectrum diagram of speech used in commercial telephony. State its bandwidth.* (*3 min*)

**A4**



Bandwidth = 3400 − 300 = 3100 Hz.

***Q5*** *Determine the periodic time for a 240 V 50 Hz mains electricity supply.* (*2 min*)

**A5**

$$\text{The periodic time} = \frac{1}{\text{frequency}},$$

$$= \frac{1}{50}\ \text{s} \quad \text{or} \quad 20\ \text{ms}.$$

***Q6*** *State briefly why it is necessary to use a high-frequency carrier for each of the following:*

(*a*) *telephony channels on a cable system, and*
(*b*) *telephony channels on a radio system.* (*3 min*)

**A6** (*a*) A carrier is used on cable systems to enable more than one speech circuit to be carried on a pair of wires.

(*b*) A carrier is used for radio systems because effective radiation does not occur below 10 kHz.

***Q7*** *If, for some reason, the permanent magnet in a rocking-armature receiver lost all its magnetism, what would be the overall effect on its operation. Give reasons for your answer.* (*4 min*)

**A7** The receiver would not work at all because the magnetic field produced by each of the 2 coils would have an equal force on the armature so that it would not move by any appreciable amount.

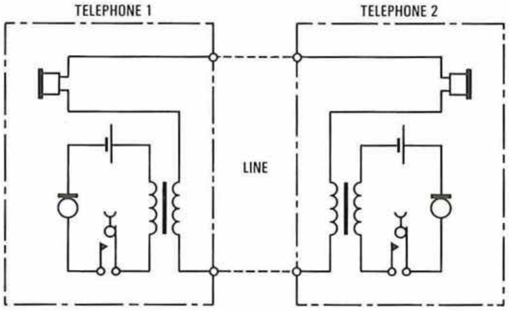
***Q8*** *If, for some reason, a carbon granule transmitter lost about half of the granules, what would be the overall effect on its operation. Give reasons for your answer.* (*4 min*)

**A8** The transmitter would not function correctly because the resistance between the 2 electrodes would be greatly increased since the granules would have a poor contact between each other. This could also cause noise from sparking between the granules (sometimes known as *frying*).

***Q9*** (*a*) *Draw a simple local-battery telephony system using only 2 telephones. Give one advantage of the system.*

(*b*) *State the signalling system normally used on such a link.* (*5 min*)

**A9** (*a*)



The main advantage of this system is that it can be installed simply, since the telephones require only a pair of wires to link them together.

(*b*) AC signalling using a hand-turned generator.

***Q10*** *Explain the function of each of the following exchanges:*

(*a*) *local exchange* (*LE*),
(*b*) *area exchange* (*AE*),
(*c*) *group switching centre* (*GSC*),
(*d*) *zone centre* (*ZC*),
(*e*) *transit switching centre* (*TSC*), *and*
(*f*) *international switching centre* (*ISC*). (*5 min*)

**A10** (*a*) A local exchange is used on the telephone network and concentrates the telephones in a particular area together.

(*b*) An area exchange is used on the telegraph (Telex) network and concentrates the Telex stations in a particular area.

(*c*) A group switching centre concentrates telephone traffic from several LEs through to other GSCs and to TSCs or an ISC.

(*d*) A zone centre concentrates telegraph traffic through to other zone exchanges and to the ISC.

(*e*) A transit switching centre carries the traffic which cannot be carried by the GSCs; this amounts to about 5% of the total.

(*f*) There are 2 main types of international switching centre: one for telephone traffic and the other for Telex. Each type carries its respective traffic to networks outside the UK.

***Q11*** *The wipers on a 200-outlet 2-motion selector are found to be standing at level 6 on the banks. How many possible outlets could there be available on this one level?*

(*a*) *10,*
(*b*) *20,*
(*c*) *100, or*
(*d*) *200?* (*1 min*)

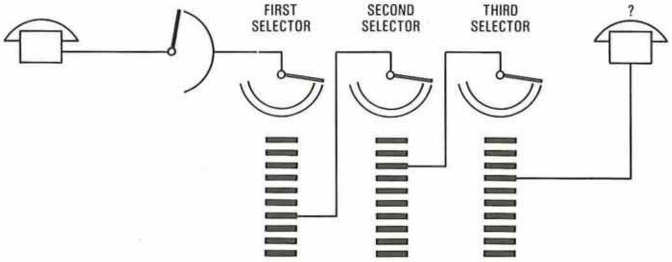
**A11** (*b*) 20.

***Q12*** *Preferably in one word, describe the main advantage given by all the following local line plant components: main distribution frame, primary cross-connection point, secondary cross-connection point and distribution point.* (*1 min*)

**A12** Flexibility.

[*Tutorial note:* They all allow flexibility between incoming pairs of wires and outgoing pairs at a particular point in the network.]

***Q13*** (*a*) *If the selectors shown below are positioned on the first bank outlet, state the number of the called customer.*



(*b*) *Name all the supervisory tones that are available from each of the selectors.* (*7 min*)

**A13** (*a*) 4871.

(*b*) (*i*) *First Selector* Dial tone, equipment busy tone and number unobtainable tone.

(*ii*) *Second Selector* Equipment busy tone and number unobtainable tone.

(*iii*) *Third Selector* Equipment busy tone, ringing tone, engaged tone and number unobtainable tone.

***Q14*** *State the main difference, in terms of the system control, between an exchange as shown in Q13, and a common-control exchange.* (*4 min*)

**A14** The exchange in Q13 is a Strowger exchange, where the call control is distributed throughout the path of the call. In a common-control exchange, call control is at a central point and is then common to all the call paths used.

***Q15*** (*a*) *Give the general name for the type of switches used in all common-control exchanges.*

(*b*) *If such a switch can carry a maximum of 10 simultaneous calls yet has 15 outlets, determine*

(*i*) *the number of inlets on the switch, and*
(*ii*) *the total number of crosspoints on the switch.* (*3 min*)

**A15** (*a*) Matrix switch.

(*b*) (*i*) 10 inlets.

(*ii*) Total number of crosspoints =

$$\text{inlets} \times \text{outlets} = 10 \times 15 = \underline{150}.$$

***Q16*** (*a*) *Describe the difference between an analogue and a digital signal.*

(*b*) *Complete the following table to show which devices are most likely to be analogue and which digital.*

| *Device* | *Digital* | *Analogue* |
|---|---|---|
| *Modern home computer* | | |
| *Grandfather clock* | | |
| *Thermometer with mercury bulb* | | |
| *Voltmeter with numerical display* | | |
| *Signalling lamp* | | |
| *Indian smoke signals* | | |
| *Diaphragm in a rocking-armature receiver* | | |
| *Computer input to a modem* | | |
| *Line output from a modem* | | |

(*4 min*)

**A16** (*a*) A digital signal has 2 or more constant voltage levels, whereas an analogue signal is continuous and can take any level.

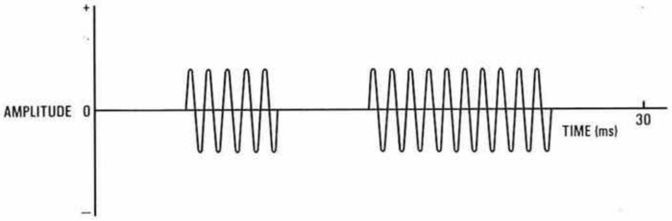
(*b*)

| Device | Digital | Analogue |
|---|---|---|
| Modern home computer | ✓ | |
| Grandfather clock | | ✓ |
| Thermometer with mercury bulb | | ✓ |
| Voltmeter with numerical display | ✓ | |
| Signalling lamp | ✓ | |
| Indian smoke signals | ✓ | |
| Diaphragm in a rocking-armature receiver | | ✓ |
| Computer input to a modem | ✓ | |
| Line output from a modem | | ✓ |

*Q17 Describe the type of long-distance telecommunications network where a datel modem would not be necessary.* (*2 min*)

**A17** Since computer signals are basically all digital, modems would not be required on an all-digital telecommunications network.

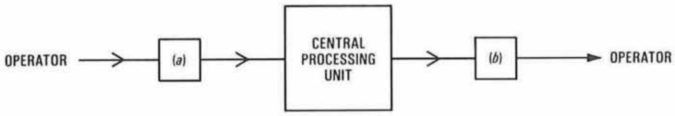
*Q18 Determine the binary number represented by the following signal for the time period 0–30 ms. Each binary digit takes 5 ms.* (*2 min*)



**A18** The equivalent binary number is 010110.

[*Tutorial note:* The right-hand side of the wave refers to the lower-order binary digit.]

*Q19 A simple block diagram of a computer system is shown below. Label blocks* (*a*) *and* (*b*) *and give a typical device for each.* (*3 min*)



**A19** (*a*) Input device; for example, keyboard.

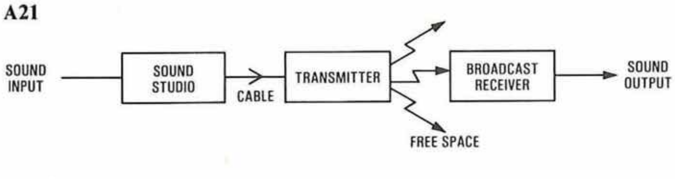
(*b*) Output device; for example, visual display unit or printer [only one answer is required].

*Q20 State 2 examples of media through which radio waves can be propagated, and one through which radio waves cannot be propagated.* (*3 min*)

**A20** Radio waves can be propagated through a vacuum and insulating materials, but not through conductors since they reflect radio waves.

*Q21 Draw and label a block diagram of a commercial radio broadcast system with a minimum of 3 blocks and showing at least 2 different media. Clearly label the input and output of the system.* (*4 min*)

**A21**



*Q22* (*a*) *State the upper limit of frequency of an ionospheric wave.*

(*b*) *Describe what would happen to such a wave if the frequency exceeded this limit.*

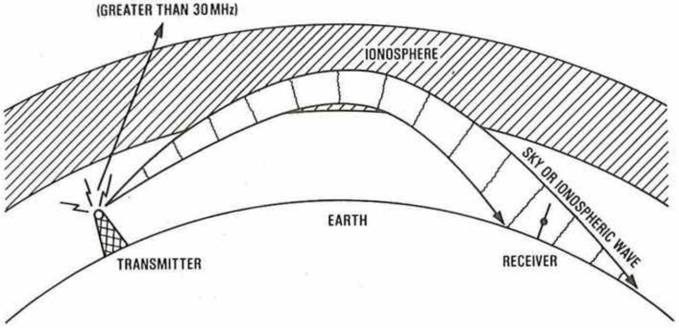
(*c*) *Sketch the path taken by each of these waves.*

(*5 min*)

**A22** (*a*) The upper limit is 30 MHz.

(*b*) A signal with a frequency above this limit and directed towards the ionosphere would not be refracted and would become a space wave.

(*c*)



*Q23 State why a modem is required in a data circuit, and identify the type of signal at the input of the modem and at the output to the transmission line.* (*6 min*)

**A23** The existing telephone network is mainly analogue, and there are many devices that do not allow the passage of DC signals of the type from computers. These signals are normally termed *digital signals.* It is necessary to convert these digital signals into a form that can pass over the telephone network—that is, convert them into analogue signals—and to convert them back at the receiving end. The device that performs this function is called a *modem.* A modem at the transmitting end receives digital signals at its input and converts them to analogue signals for transmission to line; a modem at the receiving end converts the analogue signals to digital signals.

*Q24* (*a*) *Give 4 different examples of the number of picture lines that are used, or have been used, in various television systems around the world. Include in your answer the number of lines used in the ultra-high-frequency* (*UHF*) *system used in the UK.*

(*b*) *State which of your answers produces the best picture quality.*

(*c*) *Give reasons why you think other countries have chosen a different number of lines.*

(*8 min*)

**A24** (*a*) Examples of the number of picture lines in television systems are

(*i*) 405 lines, the old very-high-frequency (VHF) UK standard;
(*ii*) 525 lines, the current American standard;
(*iii*) 625 lines, the current UK UHF standard; and
(*iv*) 819 lines, the old French standard.

[*Tutorial note:* Many others are used around the world, but they are all in this range.]

(*b*) Of the answers given in part (*a*), the 819-line picture produces the best quality.

[*Tutorial note:* The greater the number of lines, the better the picture quality.]

(*c*) When the number of lines to be used in a system is being chosen, it is necessary to achieve a balance between the cost of producing more lines and the factors that make a picture of acceptable quality to the human eye.

*Q25* (*a*) *State the number of lines in the UK ultra-high-frequency* (*UHF*) *television system that cannot normally be seen by the viewer.*

(*b*) *State the additional service that is now provided using some of these hidden lines, and briefly describe its operation.*

(*c*) *State the 2 trade names given to this service.*

(*6 min*)

**A25** (*a*) Approximately 50 lines.

[*Tutorial note:* Of the 625 lines only about 575 are used to actually display the normal picture.]

(*b*) The service is Teletext. Teletext is the reception off the air of up-to-the-minute news and information displayed in newspaper style on the screen of a domestic television receiver. With the aid of a decoder and an associated controlling keypad, normal television programmes can be replaced with one of many pages of text.

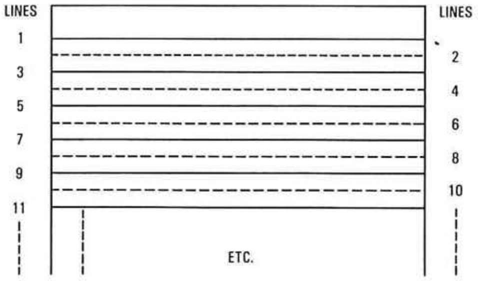
(*c*) The 2 trade names are:

(*i*) Oracle, for the Independent Broadcasting Authority's (IBA's) service, and

(*ii*) Ceefax, for the British Broadcasting Corporation's (BBC's) service.

*Q26 Given the number of picture lines adopted in the ultra-high-frequency (UHF) television system in the UK, describe the method used for transmission that directly improves picture quality. Illustrate your answer with a suitably labelled sketch.* *(6 min)*

**A26** The television picture consists of 2 sets of an equal number of lines that are fully interlaced. The first set of lines is transmitted and these cover the full area of the screen. This is then followed by the second set of lines, which are interlaced with the first set to form a complete picture (see sketch).



*Q27 (a) State the trade name of the national videotext system currently in use in the UK.*

*(b) Write a short essay (about 400 words) on how you think this system could have an important impact on one of the following:*

- *(i) shopping,*
- *(ii) libraries,*
- *(iii) newspapers,*
- *(iv) travel,*
- *(v) where people live in relation to their place of work, or*
- *(vi) education.* *(30 min)*

**A27** (*a*) Prestel.

(*b*) The essay should take one of the listed topics and describe how Prestel could change, or is changing, peoples' use of that system. It should give some indication of whether such changes will increase in the future and try to draw some conclusions on whether this is desirable.

[*Tutorial note:* Apart from marks being allocated for technical accuracy, marks would also be awarded for layout, correct sequence and general neatness.]

*Q28 List the 2 main types of navigational radar and briefly explain the differences between them.* *(4 min)*

**A28** The 2 basic forms of radar are:

(*a*) primary, and
(*b*) secondary.

Primary radar is normally carried by both ships and aircraft and makes use of the fact that radio waves are reflected by objects such as land mass, buildings, buoys, other ships etc. The reflected wave is used to fix the position of such objects relative to the sources of the wave itself.

Secondary radar is a very strong signal source permanently positioned and giving its identification to any radar receiver coming into its area. These stations are commonly referred to as *radar beacons.*

*Q29 Describe briefly how the A-scope display of a radar system can easily be calibrated in a practical way.* *(5 min)*

**A29** The radar pulse is transmitted at precisely the same time as the time base of the screen commences to deflect the beam across the screen. If the radar pulse is directed at some known target where the distance is known (say 1 nautical mile), then, when the reflected pulse causes a vertical deflection of the beam on the screen, that point can be marked as 1 nautical mile.

The calibration can now be completed since any distance across the screen is in the same proportion to any new target; that is, twice the distance across the screen corresponds to a target 2 nautical miles away.

*Q30 State 3 measurements that are needed to fix the precise position of any target.* *(3 min)*

**A30** (*a*) Range or distance,
(*b*) bearing or angle, and
(*c*) height or altitude.

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## TEC: RADIO II

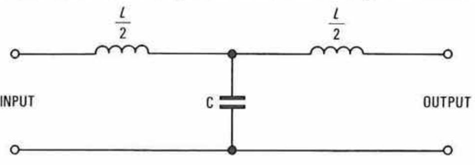
### TEC unit number U81/754. Students are advised to read the notes on p. 65

*Q1 (a) Define the meaning of the term 'characteristic impedance ($Z_0$)' of a transmission line.*

*(b) Sketch the equivalent circuit of a short length of loss-free transmission line suitable for radio frequencies.* *(5 min)*

**A1** (*a*) The characteristic impedance ($Z_0$) of a transmission line is the impedance measured at the input of an infinite length of that line.

(*b*)



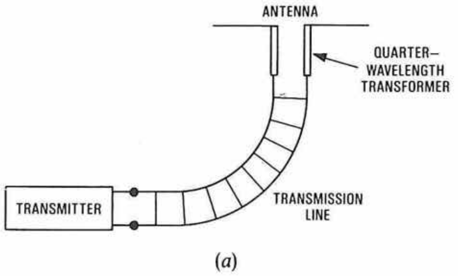
*Q2 With the aid of sketches, describe a quarter-wavelength transformer. (A mathematical answer is not required.)* *(10 min)*

**A2** A quarter-wavelength transformer is a section of transmission line, one quarter of a wavelength in length, that is used as an impedance matching device.

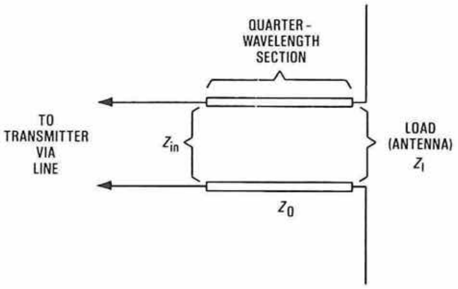
Sketch (*a*) shows the transformer being used to match a transmission line to an antenna; the line and the antenna have different values of impedance. Sketch (*b*) shows the quarter-wavelength section.

As a radio-frequency signal travels along the transmission line to the antenna, standing waves are set up along the quarter-wavelength section, so that its input and output impedances have different values.

It can be shown that the input impedance ($Z_{in}$) depends on the characteristic impedance ($Z_0$) of the section and on the impedance of the load ($Z_1$) connected to it. This means that a quarter-wavelength transformer can be designed with a particular value of characteristic impedance so that a transmission line, for example, can be matched to the different input impedance of an antenna.



(*a*)



(*b*)

[*Tutorial notes:*

(*a*) The quarter-wavelength transformer works correctly only at the designed frequency.

(*b*) The quarter-wavelength transformer can be a coaxial type to suit that type of transmission line.]

*Q3 Calculate the characteristic impedance of a radio-frequency transmission line that has the following constants:*

*(a) inductance/kilometre loop,* $L = 0{\cdot}25\ \mu H/m$*, and*
*(b) capacitance/kilometre,* $C = 100\ pF/m$*.* (*8 min*)

**A3** The characteristic impedance, $Z_0$, is given by

$$\begin{aligned} Z_0 &= \sqrt{\left(\frac{L}{C}\right)}, \\ &= \sqrt{\left(\frac{0{\cdot}25 \times 10^{-6}}{100 \times 10^{-12}}\right)}, \\ &= \frac{1}{\sqrt{4 \times \sqrt{(10^{-4})}}}, \\ &= \frac{100}{2}, \\ &= \underline{50\ \Omega.} \end{aligned}$$

*Q4 Referring to the propagation of a radio wave, indicate whether the following are true or false.*

*(a) A horizontally-polarised wave has a magnetic field parallel to the earth's surface.* TRUE/FALSE
*(b) A vertical receiving antenna receives a radio wave more efficiently if the wave is vertically polarised.* TRUE/FALSE
*(c) The electric and magnetic fields of a radio wave lay mutually at right angles and alternate in the direction of propagation.* TRUE/FALSE
*(d) The electric field strength of a radio wave is measured in volts per kilometre.* TRUE/FALSE
(*6 min*)

**A4** (*a*) False. [*Tutorial note:* The electric field lays parallel to the earth's surface.]
(*b*) True.
(*c*) False. [*Tutorial note:* The electric and magnetic fields also alternate at right angles to the direction of propagation.]
(*d*) False. [*Tutorial note:* It should be volts per metre (V/m).]

*Q5 The following statements ((a)–(d)) refer to either a half-wavelength vertical slot antenna or a half-wavelength vertical dipole antenna. Assuming free-space conditions, identify the appropriate antenna.*

*(a) The input impedance is several hundred ohms.*
*(b) It is useful for the reception of high-frequency signals.*
*(c) It has the highest gain.*
*(d) The polarisation is horizontal.*
(*5 min*)

**A5** (*a*) The slot antenna.
(*b*) The dipole antenna.
(*c*) The slot antenna.
(*d*) The slot antenna.

[*Tutorial notes:*
(*a*) The input impedance of the slot antenna is theoretically 371 Ω.
(*b*) The slot antenna is used mainly at very high frequencies (VHF) or ultra high frequencies (UHF), because at lower frequencies its size and construction make it less convenient than the half-wavelength dipole.]

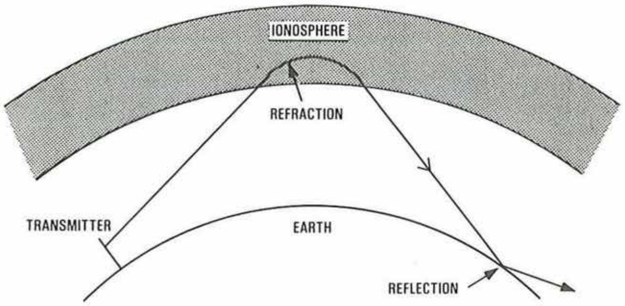
*Q6 Briefly explain the propagation characteristics of a radio signal for each of the following 2 frequencies:*

*(a) 200 kHz, and*
*(b) 20 MHz.* (*12 min*)

**A6** (*a*) A radio signal of frequency 200 kHz is propagated over a ground-wave path; that is, it travels along a path following the curvature of the earth's surface. But, in doing so, it looses energy and is attenuated. Its range is, therefore, limited to a few hundred kilometres unless an efficient antenna and large transmitter power are used. However, this method of propagation has the advantage that the signal can be received reliably during a full 24h period.

(*b*) A 20 MHz signal is propagated by a sky-wave path that takes it towards a region called the *ionosphere*, which is situated in the upper atmosphere (see sketch). On entering this region of gradually increasing ionisation density, the signal becomes progressively refracted until it is bent sufficiently to be returned to the earth. At the earth's surface, reflection takes place, returning the signal back to the ionosphere, where refraction takes place again.

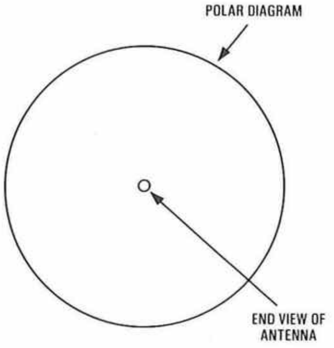
In this way, a 20 MHz signal can cover great distances, and worldwide communication is possible by using fairly simple antennas and low transmitter powers. However, because ultraviolet radiation from the sun produces the ionisation in the ionosphere, the ionisation density is very variable, and so communication between 2 stations is not reliable during a 24 h period.



*Q7 (a) Sketch the radiation pattern in the vertical plane of a half-wavelength horizontal dipole situated in free space.*
*(b) Sketch and describe how the radiation pattern given in part (a) is modified when the antenna is positioned at the following heights above the ground (assume a perfect earth):*

*(i) a quarter wavelength, and*
*(ii) one wavelength.*
(*10 min*)

**A7** (*a*) See sketch (*a*).

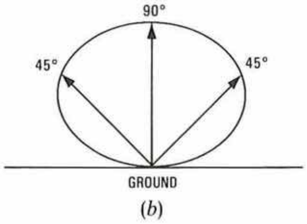


(*a*)

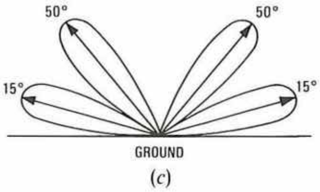
(*b*) When a signal from the horizontal antenna strikes the ground, 180° phase reversal takes place, and the result of the reflections is to alter the free-space pattern.

In (*i*), the antenna is close to the ground and, because the reflected signal has an effective path length of one wavelength, the direct wave is reinforced so that the maximum radiation takes place at high angles (see sketch (*b*)).

In (*ii*), reinforcement and cancellation takes place at the antenna, causing the pattern to split into lobes. In this case, the signal is radiated at much lower angles (see sketch (*c*)).



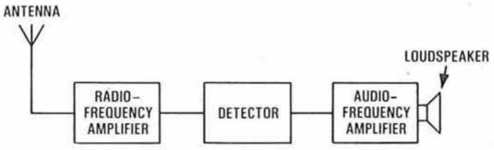
(*b*)



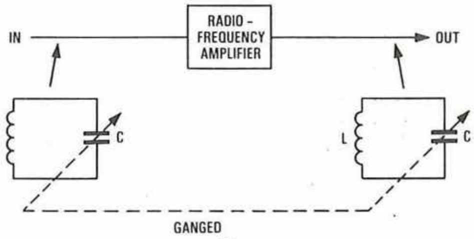
(*c*)

*Q8 Sketch and label a block diagram of a simple tuned-radio-frequency (TRF) receiver, and describe, how the radio can be tuned to cover a particular broadcast band.* (*10 min*)

**A8** Coverage of a broadcast band can be carried out with 2 tuned circuits positioned at the input and output of the radio-frequency amplifier (see sketch (*a*)). The radio is tuned by adjusting a twin-section variable capacitor so that both circuits resonate at the wanted frequency (see sketch (*b*)).



(*a*)



(*b*)

*Q9 The table below refers to a superhetrodyne radio receiver. Identify the frequencies (a), (b), (c), and (d).*

| *Signal Range* | *Oscillator Range* | *Intermediate Frequency* | *Second Channel Range* |
|---|---|---|---|
| (*a*) *to 1·54 MHz* | *1·1 MHz to* (*b*) | (*c*) | (*d*) *to 2·46 MHz* |

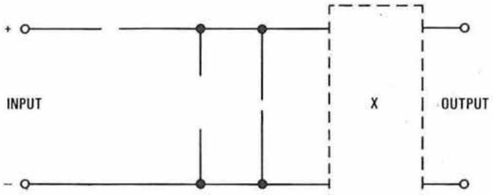
(*5 min*)

**A9** (*a*) 640 kHz
(*b*) 2 MHz
(*c*) 460 kHz
(*d*) 1·56 MHz

*Q10 List 4 shortcomings of the tuned-radio-frequency (TRF) receiver.* (*3 min*)

**A10** (*a*) Selectivity,
(*b*) sensitivity,
(*c*) stability, and
(*d*) adjacent-channel rejection.

*Q11* (*a*) *Complete the diagram shown below to form the circuit of a simple diode detector.*

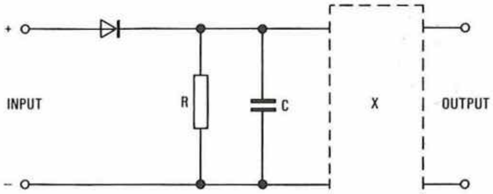


(*b*) *Identify the circuit in the box marked X, which would be used to improve the performance of the diode detector.*

(*c*) *Explain the operation of the detector circuit.*

(*10 min*)

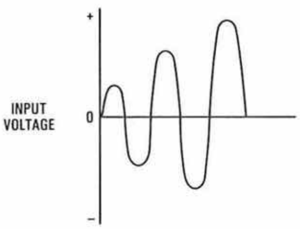
**A11** (*a*) See sketch (*a*).



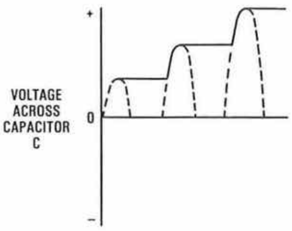
(*a*)

(*b*) Filter circuit.

(*c*) Sketch (*b*) shows an amplitude-modulated voltage waveform applied to the input of the detector circuit. On positive half cycles, the diode conducts so that current can flow into capacitor C. The voltage level across capacitor C builds up to that of each half cycle. During the negative half cycles, the diode is switched OFF, and capacitor C discharges slightly through resistor R (see sketch (*c*)). The voltage across capacitor C is, therefore, an approximation of the variations in the voltage amplitude of the input signal, which is the wanted signal.



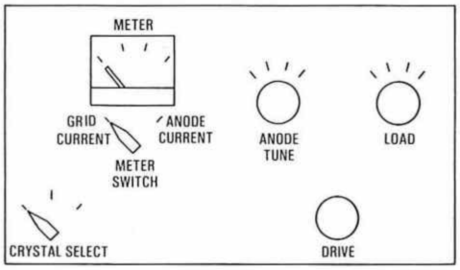
(*b*)



(*c*)

[*Tutorial note:* Because the voltage across capacitor C cannot follow the modulating waveform accurately, it contains unwanted frequencies, which are removed by the filter circuit.]

*Q12* (*a*) *The control layout of a low-power continuous-wave (CW) transmitter is shown below. Outline a suitable procedure to be followed so that maximum power can be transferred to an antenna.*



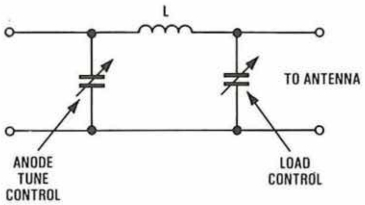
(*b*) *Briefly explain the function of the controls that are used to match the transmitter to the antenna.*

(*12 min*)

**A12** (*a*) Assuming that a suitable antenna is connected to the transmitter, the procedure is as follows:

(*i*) Select the required signal frequency.
(*ii*) Set the meter switch to GRID CURRENT.
(*iii*) Adjust the DRIVE control for a maximum grid-current reading.
(*iv*) Set the meter switch to ANODE CURRENT.
(*v*) Adjust the ANODE TUNE control for a dip in the anode-current reading.
(*vi*) Adjust the LOAD control for a higher reading of anode current.
(*vii*) Continue re-adjusting the ANODE TUNE and LOAD controls so that the anode current is increased up to a maximum value for the power amplifier.

(*b*) The ANODE TUNE and LOAD controls form part of an LC $\pi$ network (see sketch) and allow the transmitter to be matched over a small range of impedances that might be presented by the antenna. The ANODE TUNE control allows the output circuit to be tuned to resonance, which is shown by the dip in the anode current reading, while adjustment of the LOAD control couples power to the antenna.



*Q13 Indicate whether the following statements are true or false.*

(*a*) *In a high-level modulation system, the modulation is carried out at the final radio-frequency power stage.* *TRUE/FALSE*

(*b*) *A low-level modulation system is more suitable for high-power transmitters.* *TRUE/FALSE*

(*3 min*)

**A13** (*a*) True.

(*b*) False. [*Tutorial note:* In the interests of transmitter efficiency, a high-level system is used so that more power amplification can take place in class C amplification stages.]

*Q14* (*a*) *Explain the need for frequency stability in a radio transmitter that uses a variable-frequency oscillator.*

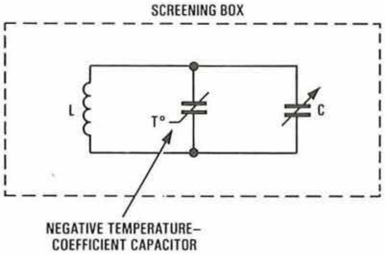
(*b*) *Describe, with the aid of a simple sketch, how this can be achieved.* (*10 min*)

**A14** (*a*) The frequency radiated by a transmitter must not drift from its designed value; that is, it must be sufficiently stable for correct reception by a selective receiver and to stop interference to adjacent channels.

(*b*) Frequency drift is likely to occur because of temperature changes affecting the values of the inductors and capacitors in the tuned circuit. The tuned circuit, therefore, should be isolated by enclosing it in a suitable screened box. Other important points are as follows:

(*i*) using good quality components, and

(*ii*) fitting a negative temperature capacitor to cancel out the changes in component values (see sketch).



[*Tutorial note:* Several other precautions are usually taken, such as:

(*a*) using a buffer amplifier between the oscillator and succeeding stages,

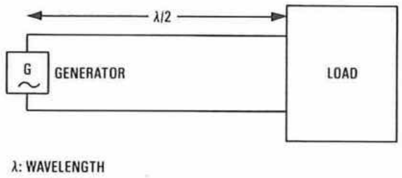
(*b*) stabilising the high-tension supply to the oscillator, and

(*c*) using a rigid mechanical construction.]

*Q15* *State the type of load presented to the generator in the circuit shown below, if the line is connected in turn to the following:*

(*a*) *a short circuit, and*

(*b*) *a capacitive reactance.* (*3 min*)



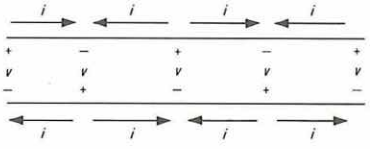
**A15** (*a*) Short circuit.

(*b*) Capacitive reactance.

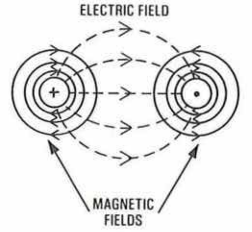
[*Tutorial note:* The behaviour of a half-wavelength line in reproducing the load impedance at its input is particularly useful because it allows measurements of a load to be made even though the actual load might be inaccessible, as, for example, with measurements on an antenna.]

*Q16* *Explain briefly why there is negligible transmission of radio waves from a balanced-twin transmission line used to connect an antenna to a radio transmitter.* (*10 min*)

**A16** It is assumed that the 2 lines are close together and that at any instant equal currents flow in each line. Sketch (*a*) shows a section of the twin line and the instantaneous currents (*i*) and voltages (*v*). Sketch (*b*) shows a cross-section and the electric and magnetic fields at one instant. The electric field is contained between the 2 conductors, while the 2 magnetic fields are in opposition and cancel, so that there is only negligible radiation.



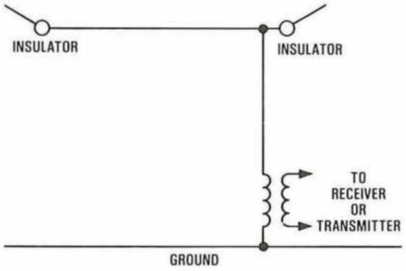
(*a*)



(*b*)

*Q17* *Sketch and describe an antenna suitable for the reception or transmission of radio signals having long wavelengths.* (*10 min*)

**A17** At long wavelengths, transmission is by a vertically-polarised ground wave, which, ideally, requires the use of a quarter-wavelength vertical antenna. However, it would need to be several hundred metres in length, making erection difficult and costly. For this reason, a compromise antenna such as an inverted-L antenna can be used (see sketch).



The vertical section is as long as is practical. The horizontal top section has the effect of adding capacity so that the effective length of the antenna is increased, and electrically its length becomes a quarter wavelength.

High conductivity at the ground in the vicinity of the antenna is necessary, and an artificial earth mat, or a counterpoise antenna, may be required to achieve this.

[*Tutorial notes:*

(*a*) Effective ground-wave propagation is possible from a vertical antenna up to a height of about five-eighths of a wavelength. Beyond this, some of the radiation tends to be at too high an angle.

(*b*) Other suitable antennas are the T and vertical antenna with capacity hat; both are designed to increase the effective length by adding extra capacity.]

*Questions and answers contributed by M. J. Wray*

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## TEC: TRANSMISSION SYSTEMS II

**TEC unit number U81/746. Students are advised to read the notes on p. 65**

*Q1* *What restricts the bandwidth of a local subscriber-to-subscriber telephone transmission?* ($\frac{1}{2}$ *min*)

**A1** The frequency response of the components used in the transmission link.

[*Tutorial note:* Components such as the cable, transmission bridge, telephone transmitter and receiver.]

*Q2* *Identify the transmission signal represented by each of the following frequency ranges:*

(*a*) *300 Hz–3400 Hz* (*b*) *0–5·5 MHz* (*c*) *0–120 Hz.* ($\frac{1}{2}$ *min*)

**A2** (*a*) Speech signal

(*b*) Video signal

(*c*) Telegraph signal

*Q3* *The commercial frequency ranges allocated to telegraph, speech, music and video baseband signals are all different. Broadly outline the reasoning for this difference and quote typical frequency ranges.* (*8 min*)

**A3** The primary requirement of a transmission system is to ensure that no loss of information occurs between the originator and the receiver.

In speech transmission, the speaker generates frequencies in the range 100 Hz–10 000 Hz. However, all the relevant information of the transmission will be contained within the frequency range 300 Hz–3400 Hz. By transmitting only these latter frequencies, some loss of signal power and voice recognition occurs, but no loss of information results.

The frequencies generated by musical instruments range from 50 Hz–15 000 Hz. The listener will want to understand and enjoy any musical transmission; thus as many of these frequencies as possible will need to be transmitted. Most of the frequencies above 10 000 Hz are beyond the threshold level of the average human ear and, therefore, no apparent loss of information will occur if these higher frequencies are removed from the transmission. A high-quality music transmission would have a frequency range of 100 Hz–10 000 Hz.

The frequencies generated at the source of a video transmission range from 0–6·51 MHz. This wide range is due to the large amount of picture information which must be transmitted. Synchronising signals increase this range to well over 7 MHz. In practice, frequencies in the range 0–5·5 MHz are transmitted, and this results in some picture distortion. However, this distortion is not generally apparent to the viewer and thus no apparent loss of information occurs.

In telegraphy a 2-state signalling system is used. Ideally, only one frequency needs to be used in transmissions, the 2 states being represented by FREQUENCY ON and FREQUENCY OFF. The effect of switching rapidly from one state to the other does, however, result in the generation of a large number of frequencies. In practice most of these frequencies are suppressed and a narrow 120 Hz band is employed without loss of information.

In all these cases, the allocated frequency ranges are such as to ensure the most economic use of the carrier frequency bands available to the systems.

*Q4 A telephone, having a noisy transmitter, is used to originate a local call. When this telephone is transmitting, the worst signal-to-noise ratio will occur at*

(*a*) *the originating end,*
(*b*) *the distant receiving end, or*
(*c*) *the transmission bridge in the exchange.*

*Select the correct statement.* ($\frac{1}{2}$ *min*)

**A4** (*b*) the distant receiving end.

[*Tutorial note:* The speech and noise signal of the transmitter will be attenuated by the line. However, the line itself will increase the overall noise signal and thus signal-to-noise ratio deteriorates with distance.]

*Q5 Explain the line transmission term 'howling'.* (*1 min*)

**A5** Howling is uncontrolled oscillations in a 4-wire network caused by a mismatch between the 2-wire and 4-wire terminals.

*Q6 List 4 typical noise conditions that occur in transmission systems.* ($\frac{1}{2}$ *min*)

**A6** Resistor noise, shot noise, partition noise, galactic noise.

[*Tutorial note:* Resistor noise is sometimes referred to as *Johnson* or *thermal* noise.]

*Q7 The power of any signal propagating along a transmission line is continually decreasing. The effect on the signal is referred to as signal ..........*
*(Fill in missing word.)* ($\frac{1}{2}$ *min*)

**A7** attenuation.

*Q8 Is crosstalk a noise condition?* ($\frac{1}{2}$ *min*)

**A8** Yes

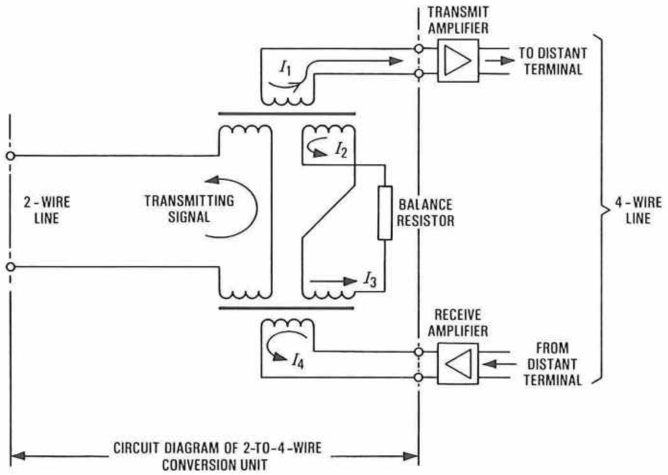
[*Tutorial note:* Any unwanted signal in a transmission system is a noise condition.]

*Q9 Why is it necessary to amplify signals at regular intervals along a transmission line?* (*2 min*)

**A9** Signals need amplifying in order to compensate for the attenuation effects of the line. Amplifiers are spaced at regular intervals along the transmission line to maintain an acceptable signal-to-noise ratio throughout the system. Amplifiers placed simply at the originating end of a line may cause excessive crosstalk in the near-end cable link. Amplifiers placed simply at the receiving end of a line will result in the line noise being amplified to an unacceptable level.

*Q10 Explain, with the aid of a circuit diagram, the principles of operation of a 2-to-4-wire conversion unit.* (*10 min*)

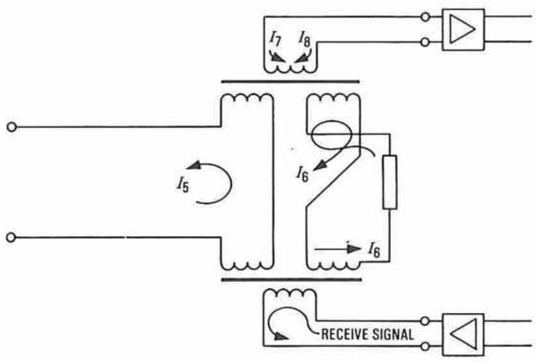
**A10** Sketch (*a*) shows the transmitting path from the 2-wire to the 4-wire circuit. The signal current in the 2-wire line induces currents $I_1$, $I_2$, $I_3$ and $I_4$ in the directions shown. $I_1$ is transmitted to the distant terminal via the transmit amplifier. $I_2$ and $I_3$ are (ideally) equal; thus no current flows in the balance circuit. $I_4$ is prevented from flowing to line by the unidirectional action of the receive amplifier. For the transmitting condition, $I_1$ and $I_4$ are of the same magnitude; therefore, only half the available signal power is utilised at the conversion unit, the line amplifiers compensating for this loss.



(*a*)

Sketch (*b*) shows the receiving path from the 4-wire to the 2-wire circuit. The signal current in the receive circuit induces currents $I_5$ and $I_6$ in the directions shown, $I_5$ flowing in the 2-wire line and $I_6$ flowing in the balance circuit. $I_5$ induces a current, $I_7$, in the transmit circuit and $I_6$ induces a current, $I_8$, in the transmit circuit. Providing $I_7$ and $I_8$ are of equal magnitude no current flows in the transmit circuit.

The function of the balance resistor is to ensure that $I_5$ and $I_6$ induce currents of equal magnitude in the transmit circuit, but this is seldom achieved in practice and some current does flow in the transmit pair. However, as long as this difference is relatively small, howling will not occur.



(*b*)

*Q11 Briefly distinguish between multiplex and space-division transmission systems.* (*2 min*)

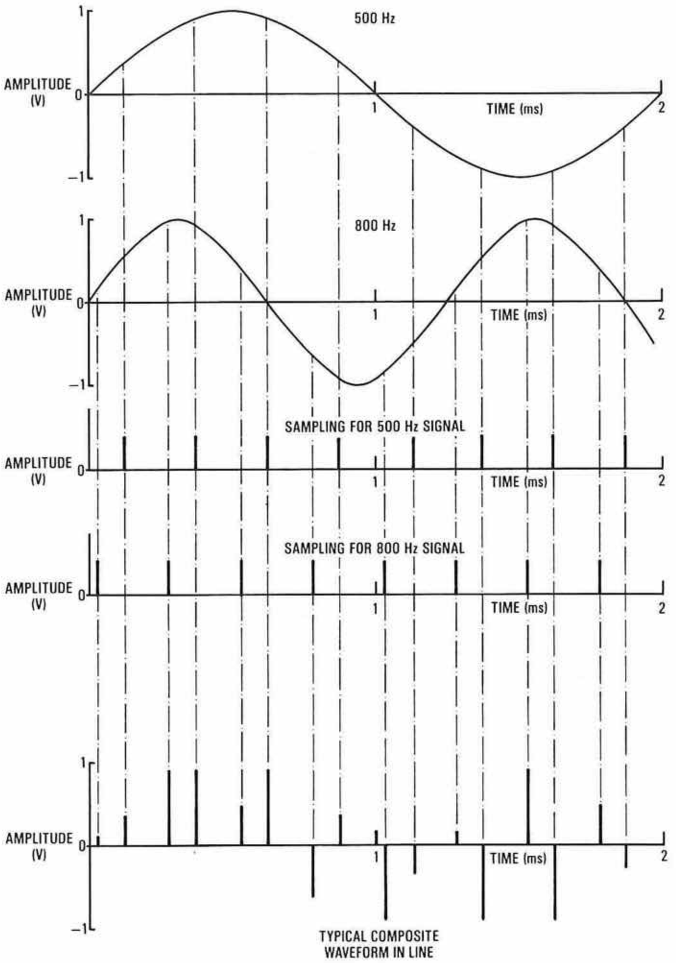
**A11** In multiplex systems several signals are simultaneously transmitted over a common path without loss of signal identity. In space-division systems each signal requires a path that is electrically isolated from any other path.

*Q12 In a time-division multiplex system, what is the advantage of transmitting all pulses at the same amplitude level?* (*1 min*)

**A12** When a constant amplitude is used for all pulses, the line noise induced into the signal is much easier to eliminate.

*Q13 Two separate signals, one 500 Hz the other 800 Hz, are transmitted simultaneously over a pulse-amplitude modulation system using time-division multiplex techniques. The sampling rate for each channel is 4000/s. Draw a typical waveform present in the transmission path over a period of 2 ms. Your drawing must clearly show how you obtained the waveform. (Assume both signals have a peak amplitude of 1 V.)* *(10 min)*

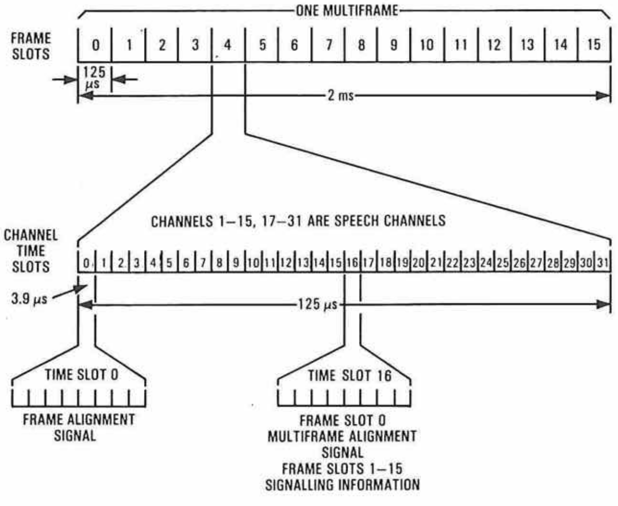
**A13**



[*Tutorial note:* Eight sampling pulses must be shown over the 2 ms period.]

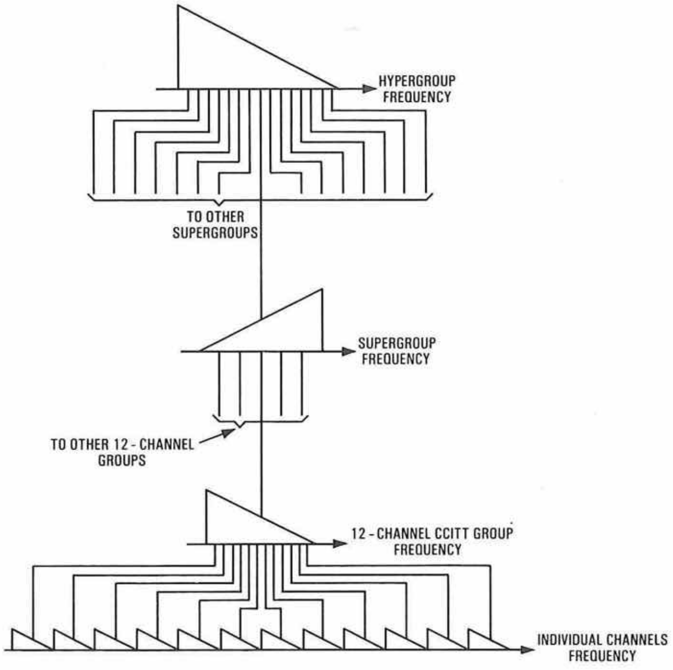
*Q14 Draw and label a diagram of the frame structure of multiframe 30-channel pulse-code modulation system.* *(5 min)*

**A14**



*Q15 Without reference to frequency values, draw frequency domain diagrams to illustrate the hierarchical layout of a CCITT hypergroup.* *(4 min)*

**A15**


HYPERGROUP FREQUENCY
TO OTHER SUPERGROUPS
SUPERGROUP FREQUENCY
TO OTHER 12 - CHANNEL GROUPS
12 - CHANNEL CCITT GROUP FREQUENCY
INDIVIDUAL CHANNELS FREQUENCY

*Q16 State the bandwidth of*

*(a) a CCITT 12-channel group,*
*(b) a supergroup, and*
*(c) a hypergroup.* *(1 min)*

**A16** (*a*) 48 kHz
(*b*) 240 kHz
(*c*) A hypergroup contains several supergroups. A fully expanded hypergroup has a bandwidth of 3716 kHz. The nominal bandwidth is 4 MHz.

*Q17 Compare the merits of space-division and frequency-division systems.* *(5 min)*

**A17** Where the number of subscribers is relatively small and the distance between subscribers relatively short, space-division systems are economically viable. As the number of subscribers and/or the distance between subscribers increases, space-division systems become expensive, bulky, difficult to expand and maintain; and the cable network becomes extremely complicated as the number of subscribers increases. Each trunk circuit requires its own amplification circuits which adds to the cost and complexity of the network.

For large telecommunication networks, a comparable frequency-division system is cheaper than a space-division system, is easier to expand and makes better use of available duct space; it also has a relatively straightforward cable network and cable costs are lower. However, the circuitry within a frequency-division system is more complicated than a space-division system and, therefore, more skilled staff are required to install and maintain the system.

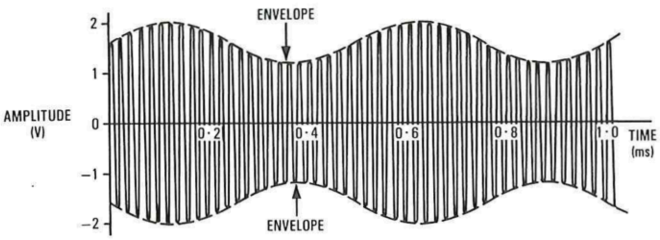
*Q18 A 50 kHz carrier is amplitude modulated by a 2000 Hz signal. The depth of modulation is 0·25 and the peak amplitude of the modulating signal is 0·4 V.*

*(a) State the frequencies present in the modulated wave.*
*(b) Determine the peak amplitude of the unmodulated carrier.*
*(c) Draw, to scale, the modulated waveform over a period of 1 ms, and clearly indicate what is meant by the term 'envelope'.*

*(8 min)*

**A18** (*a*) 48 kHz, 50 kHz and 52 kHz.
(*b*) Peak amplitude of unmodulated carrier $= 0{\cdot}4 \times 4$,
$= \underline{1{\cdot}6\ \text{V}}$.

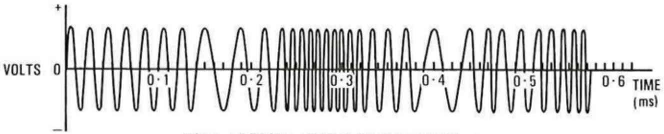
(*c*)



*Q19 The frequency of a baseband signal is always higher/lower than its carrier frequency.*
*(Delete incorrect word.)* ($\frac{1}{2}$ *min*)

**A19** Delete *higher*.

*Q20 Determine the carrier and modulating frequencies in the waveform shown below. Assume a single sinusoidal modulating frequency.* (*4 min*)



NOTE: EACH SUB-DIVISION IS EQUAL TO 0·01 ms

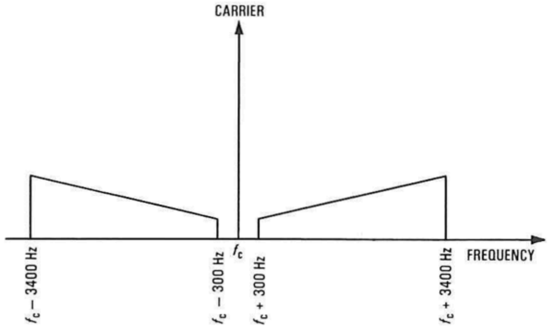
**A20** Carrier = 50 kHz.
Modulating frequency = 4 kHz.

[*Tutorial note:* For this frequency-modulated wave, the student should be able to discern where the frequency is constant. This occurs between 0 and 0·1 ms. The period of the carrier is 0·02 ms; therefore, the carrier frequency = 50 kHz.

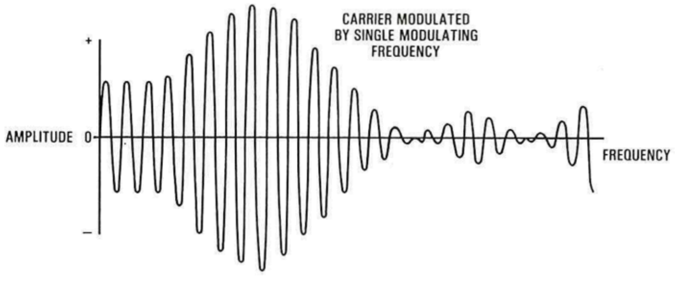
To determine the period of the modulating frequency it is necessary to detect the repeating cycle. A close look at the waveform shows that the lowest frequency occurs in time period 0·14–0·18 ms and again at 0·39–0·43 ms. Thus the period of the modulating signal is given from 0·14–0·39 ms.]

*Q21 Draw a frequency domain diagram of a carrier amplitude modulated by a baseband signal having a bandwidth of 300–3400 Hz.* ($1\frac{1}{2}$ *min*)

**A21**



*Q22 What condition is illustrated in the diagram below?* ($\frac{1}{2}$ *min*)



**A22** Overmodulation.

*Q23 A carrier is amplitude modulated by a baseband signal of 300 Hz–3400 Hz.*
*State the bandwidth for each of the following transmission systems:*

(*a*) *double sideband*
(*b*) *single sideband, and*
(*c*) *single sideband with suppressed carrier.* (*1 min*)

**A23** (*a*) 6·8 kHz
(*b*) 3·4 kHz
(*c*) 3·1 kHz

*Q24 Define frequency modulation.* (*1 min*)

**A24** Frequency modulation is the process of varying the carrier frequency in accordance with the amplitude of the modulating frequency, the amplitude of the carrier being constant.

*Q25 A carrier frequency is frequency modulated by a 3 kHz signal having a peak amplitude 0·4 of the maximum permitted level. If the rated system deviation is 60 kHz, determine the frequency deviation and the modulation index.* (*2 min*)

**A25** Frequency deviation $= 60 \times 0{\cdot}4,$
$= \underline{24\,\text{kHz.}}$

$$\text{Modulation index} = \frac{\text{frequency deviation}}{\text{modulating frequency}},$$

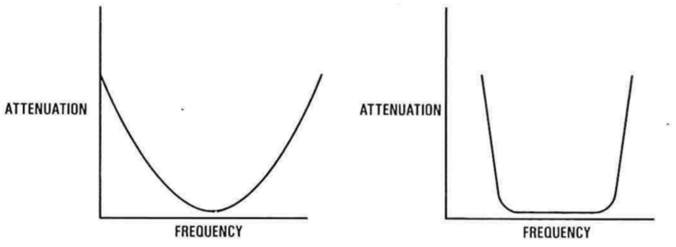
$$= \frac{24}{3},$$

$$= \underline{8{\cdot}0.}$$

*Q26 Draw typical frequency response curves for a band-pass filter using*

(*a*) *inductors and capacitors, and*
(*b*) *quartz crystal components.* (*1 min*)

**A26**

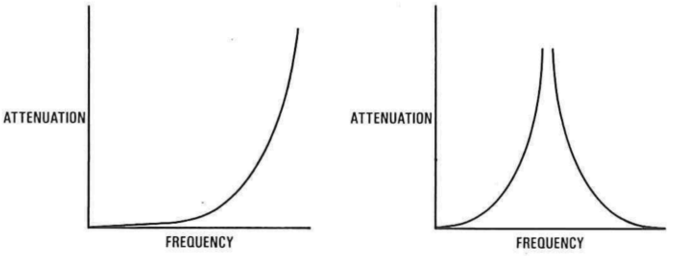


(*a*) (*b*)

*Q27 Draw typical frequency response curves for the following types of filters*

(*a*) *low-pass, and*
(*b*) *band-stop.* (*1 min*)

**A27**



(*a*) (*b*)

*Q28 What form of modulation is used where the amplitude of the modulating signal varies the angle of the carrier?* ($\frac{1}{2}$ *min*)

**A28** Phase modulation.

*Q29 A carrier has a modulation index of 0·85. If the carrier's peak amplitude is 1·2 V when no modulating signal is present, determine the peak amplitude of the modulating signal. (Assume amplitude-modulated system.)* (*2 min*)

**A29** $\text{Modulation index} = \dfrac{\text{peak amplitude of the modulating signal}}{\text{peak amplitude of the carrier}}$.

Thus the peak amplitude of the modulating signal

$$= 0{\cdot}85 \times 1{\cdot}2,$$
$$= \underline{1{\cdot}02\ \text{V}}.$$

*Q30 A signal having a frequency range of 100 Hz–15 000 Hz is transmitted by a pulse-amplitude modulation system. An acceptable sampling rate would be*

(*a*) *15 000/s* (*b*) *25 000/s* (*c*) *35 000/s.*

*(Select correct sampling rate.)* ($\frac{1}{2}$ *min*)

**A30** 35 000/s

[*Tutorial note:* Sampling rate must be at least twice the highest frequency.]

*Q31 The modulation system which is based on binary signalling is commonly known as ......... .*
*(Insert correct system)* ($\frac{1}{2}$ *min*)

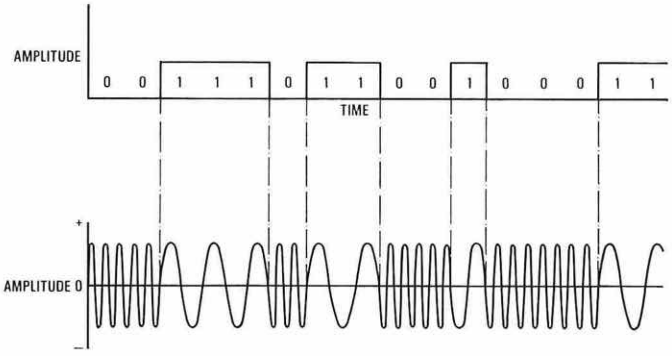
**A31** pulse-code modulation.

*Q32 Why are computer-originated signals difficult to transmit directly over the national telephone network?* (*2 min*)

**A32** Computers originate DC signals. The national network is, mainly, an analogue network allowing AC signals to be readily transmitted but severely distorting DC signals. The components which have the most adverse effect on DC signals in the national network are line amplifiers and transmission bridges.

*Q33 Briefly explain, with the aid of diagrams, how frequency modulation is used in the transmission of digital signals.* (*4 min*)

**A33** Digital signals are 2-state signals representing 0 and 1. In frequency-modulation systems, the 2 binary states are each represented by a different frequency, the system switching from one to the other as required (see sketch).



*Q34 Define the term 'demodulation'.* (*1 min*)

**A34** Demodulation is the process of recovering the baseband signals from the modulated carrier wave.

*Q35 Express the power ratio 8 : 2 in decibels.* (*1 min*)

**A35** $10 \log_{10} \dfrac{8}{2} = 10 \times 0{\cdot}6,$

$$= \underline{6\ \text{dB}}.$$

*Q36 Express + 13 dBm in terms of power units.* (*2 min*)

**A36** $+13\ \text{dBm} = 10 \log_{10} \dfrac{x}{1\ \text{mW}},$

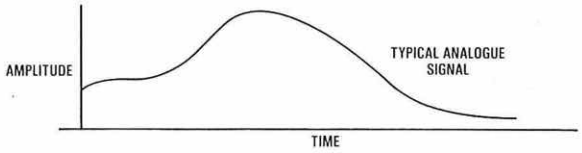
where $x$ is the output power relative to 1 mW.

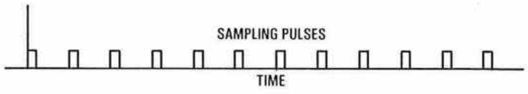
Thus $x = \text{antilog}_{10} \left(\dfrac{13}{10}\right),$

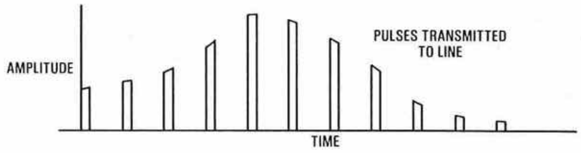
$$= \underline{20\ \text{mW}}.$$

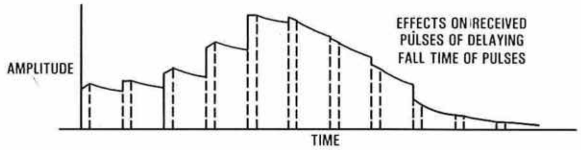
*Q37 Using simple waveform diagrams, illustrate how an analogue signal may be transmitted as a series of pulses without loss of information.* (*10 min*)

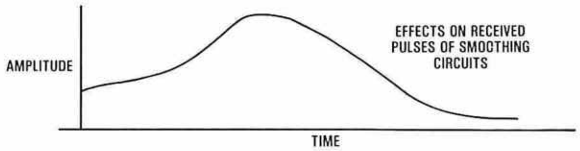
**A37**











[*Tutorial note:* The received signal is not exactly the same as the transmitted signal, the discrepancy showing up as noise. However the sampling rate ensures that this noise is kept at an acceptable level.]

*Q38 An amplifier stage provides an output signal of 25 mW when the input signal is 50 μW. Determine the gain of the stage in decibels.* (*2 min*)

**A38** $\text{Gain} = 10 \log_{10} \dfrac{25\ 000}{50},$

$$= \underline{27\ \text{dB}}.$$

*Q39 An amplifier stage has a voltage gain of 50 and a current gain of 30. Determine the power gain in decibels.* (*2 min*)

**A39** $\text{Power gain} = 10 \log_{10} (50 \times 30),$

$$= \underline{32\ \text{dB}}.$$

*Q40 The input signal to a transmission line is given as 1·4 V. If the output signal at the receive end is 0·5 mV, determine the loss in decibels.* (*2 min*)

**A40** $$\text{Loss} = 20 \log_{10} \frac{1400}{0{\cdot}5},$$
$$= \underline{69\ \text{dB}.}$$

*Q41 The signal level at a particular point in a system is 4 mV. If the noise level is 8 μV, determine the signal-to-noise ratio.* (*2 min*)

**A41** $$\text{Signal-to-noise ratio} = 20 \log_{10} \frac{4000}{8},$$
$$= \underline{54\ \text{dB}.}$$

*Q42 A radio transmission broadcasts on 240 m. Determine its frequency.* (*2 min*)

**A42** $$\text{Frequency} = \frac{300 \times 10^6}{240},$$
$$= \underline{1{\cdot}25\ \text{MHz}.}$$

*Q43 Determine the period of a wave having a frequency of 60 kHz.* (*2 min*)

**A43** $$\text{Period} = \frac{1}{60 \times 10^3},$$
$$= \underline{16{\cdot}7\ \mu\text{s}.}$$

*Q44 The wavelength of a wave in free space will be*

(*a*) *the same as . . . ,*
(*b*) *shorter than . . . , or*
(*c*) *longer than . . .*

*an identical wave propagating along an optical fibre.* (*Select correct answer.*) (*1 min*)

**A44** (*c*)

[*Tutorial note: The speed of a wave in optical fibre is lower than that of a wave in free space.*]

*Questions and answers contributed by N. C. Webber*

# SCOTTISH TECHNICAL EDUCATION COUNCIL

## Certificate in Electrical and Electronic Engineering

The questions given below are from examination papers set by the Scottish Technical Education Council (SCOTEC) and are reproduced with the permission of the SCOTEC. The answers given have been prepared by independent authors. Sometimes, additional tutorial information is given; this is enclosed within square brackets to distinguish it from the information that would be expected of students under examination conditions. Answers to some questions are occasionally omitted because of insufficient space.

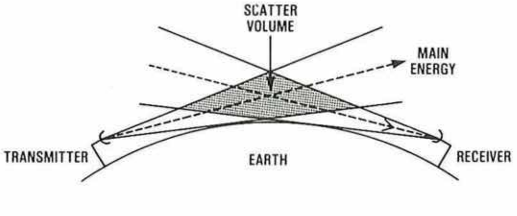
### SCOTEC: RADIO III 1982

**Students were expected to attempt all questions from Section A and 4 questions from Section B. Each question in Section A carried 5 marks and each question in Section B carried a total of 25 marks. The total time allowed for the paper was 3 h.**

### SECTION A

*Q1 With the aid of a sketch, briefly describe a tropospheric scatter link.*

**A1** A communication link may be possible at frequencies above 500 MHz when turbulence changes the refractive index of the atmosphere. The scattering (see sketch) that ensues results in a very weak signal and, consequently, high-gain aerials are necessary.



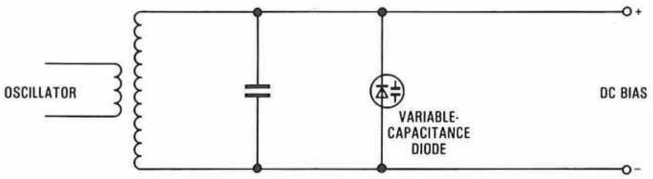
*Q2 Distinguish between modulation and depth of modulation.*

**A2** Modulation factor is the ratio of the amplitude of the modulating signal to that of the carrier signal.

Depth of modulation is the above ratio expressed as a percentage.

*Q3 With the aid of a circuit diagram, describe how a variable capacitance diode can stabilise an oscillator.*

**A3**



See sketch. A sample of the signal is rectified and used to reverse bias the variable-capacitance diode. A change of DC voltage level changes the capacitance of the diode, which corrects the error of the resonant frequency of the oscillator.

[*Tutorial note:* The drift in frequency is sampled by a phase comparator.]

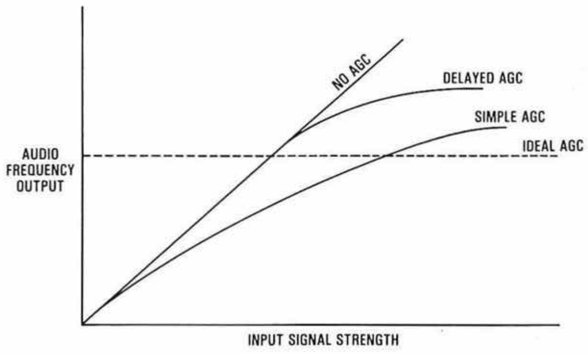
*Q4* (*a*) *Why is automatic gain control* (*AGC*) *employed in a radio receiver?*

(*b*) *Distinguish between simple and delayed AGC.*

**A4** (*a*) If there is any variation in the signal strength at the receiver aerial, then there is a corresponding variation in the audio-frequency output from the receiver. These variations in output are reduced when AGC is employed.

(*b*) Simple AGC produces feedback voltages on weak as well as strong signals.

Delayed AGC is an improved method because the feedback voltage is ineffective until the incoming signal exceeds a predetermined level (see sketch).

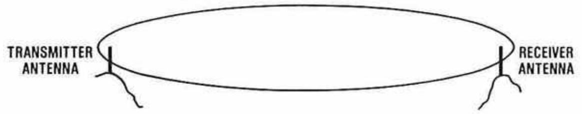


*Q5* (*a*) *What is meant by the term 'standing-wave ratio (SWR)'.*
(*b*) *What does the presence of standing waves indicate?*

**A5** (*a*) The SWR is the ratio of the maximum standing-wave voltage to the minimum standing-wave voltage on a transmission line.
(*b*) Standing waves occur when a transmission line is not terminated by the characteristic impedance of that line. Hence the presence of standing waves indicates a mis-match.

*Q6* (*a*) *With the aid of a sketch describe the first fresnel zone.*
(*b*) *What precautions are necessary to ensure that a direct wave is in free space?*

**A6** (*a*) Diffraction causes a signal to spread over a limited region, forming an ellipsoid which is known as the *first fresnel zone.* (See sketch.)



(*b*) Only if the entire fresnel zone is clear of obstacles can it be assumed that a direct ray is in free space.

*Q7* (*a*) *Distinguish between the effects of super refraction and sub refraction.*
(*b*) *At what frequencies are these phenomena most prevalent?*

**A7** (*a*) Super refraction tends to occur in the tropics and results in an extension of the propagated signal range.
Sub refraction occurs in higher latitudes and results in a shortening of the propagated signal range.
(*b*) The effects of sub and super refraction are most felt at radar frequencies and can result in false ranges being displayed.

*Q8* *Give* THREE *types of noise generated in a radio receiver and briefly explain their source.*

**A8** (*a*) *Thermal Noise* Electrons in a conductor are in random motion, their agitation increasing as the temperature increases. The random motion leads to a randomly varying potential.
(*b*) *Partition Noise* Noise can be caused by random fluctuations in the division of current between the terminals of active electronic devices (for example, the division of the current in a transistor between base and collector).
(*c*) *Microphonic Noise* Mechanical shock or vibration of an electronic valve can result in noise caused by changes in the physical position of the electrodes.

*Q9* *Define intermodulation noise.*

**A9** Intermodulation noise can occur in multichannel communication systems. It results from non-linearity in amplifiers. The interference increases with increase in signal level.

*Q10* *Draw a block diagram of a microwave link giving operational frequencies and power levels.*

**A10** See A8, SCOTEC: Radio III, *Supplement*, Oct. 1982, Vol. 1, p. 62.

## SECTION B

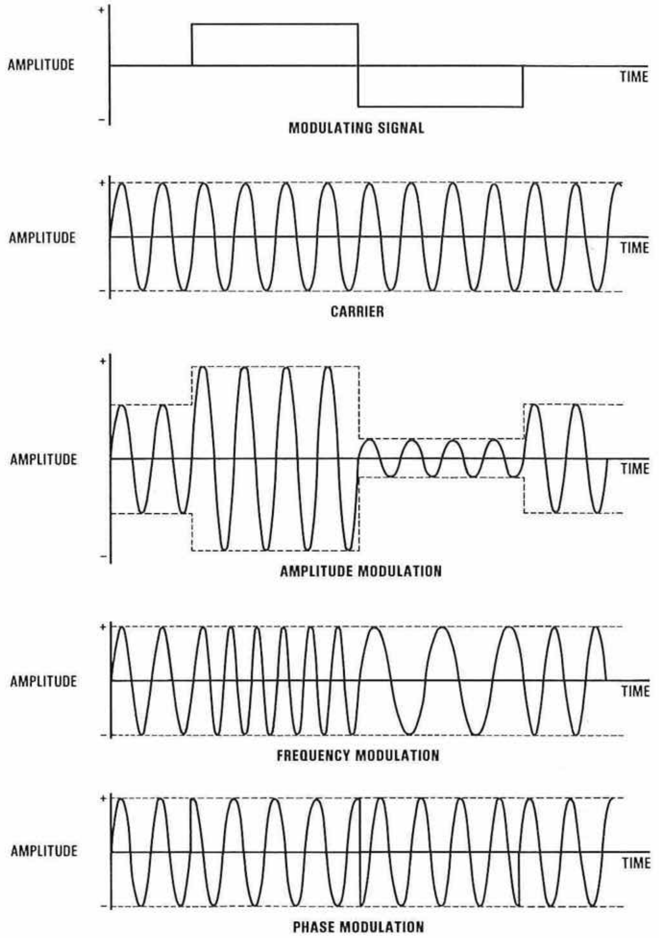
*Q11* (*a*) *With the aid of a sketch distinguish between:*

(*i*) *amplitude modulation,*
(*ii*) *frequency modulation, and*
(*iii*) *phase modulation.*

(*b*) *For any* TWO *of Q11(a), give* ONE *example where that form of modulation is used, stating typical carrier frequencies and bandwidths.*
*Give reasons for the typical values selected.*
(*c*) *Show, on a phasor diagram, how noise would appear on the* TWO *methods of modulation selected in Q11(b).*

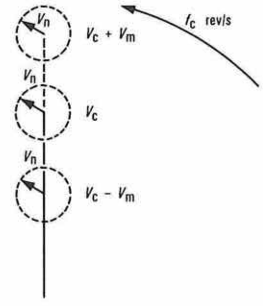
**A11** (*a*) See sketch (*a*).

[*Tutorial note 1:* Alternatively, phasor diagrams showing the angular displacement of the carrier could have been given.
*Note 2:* In the sketches given, a square wave has been used for the modulating voltage as this illustrates more clearly the difference between frequency and phase modulation.]

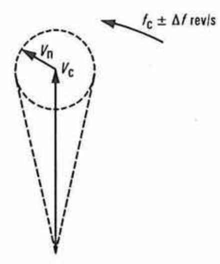


(*a*)

(*b*) Amplitude modulation is used in broadcasting, where a typical carrier frequency and bandwidth is 200 kHz and 10 kHz, respectively. This carrier frequency enables long-distance communications, and the bandwidth is relatively narrow enough to enable more channels of communication to operate.
Frequency modulation is used in local broadcasting, typically with a carrier frequency of approximately 100 MHz and a bandwidth of 150 kHz. Very-high frequency communications have short distances but allow a wider bandwidth.
(*c*) Phasor diagrams for amplitude modulation and frequency modulation are shown in sketches (*b*) and (*c*), respectively, $V_c$, $V_m$ and $V_n$ are the voltages of the carrier, modulating and noise signals, respectively. $f_c$ is the carrier frequency.



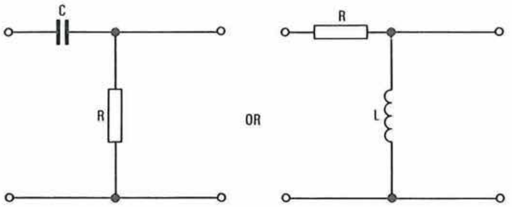
(*b*)



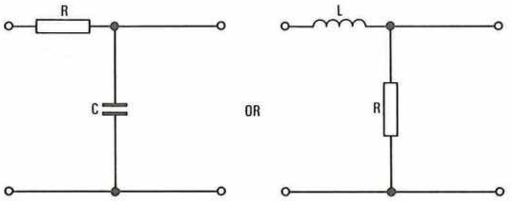
(*c*)

*Q12* (*a*) *Draw a pre-emphasis circuit.*
(*b*) *Draw a de-emphasis circuit.*
(*c*) *Explain the action of both circuits.*
(*d*) *What is the main advantage of using these circuits in a radio receiver?*
(*e*) *Give* TWO *advantages and* TWO *disadvantages of FM broadcasting.*

**A12** (*a*)



(*b*)



(*c*) *Pre-Emphasis Circuit* This circuit is in effect a high-pass filter. The capacitive reactance decreases at high frequencies (or the inductive reactance increases) and so high frequencies are attenuated less than lower frequencies.
*De-Emphasis Circuit* Again this circuit is a filter, but to compensate for the pre-emphasis, this circuit is a low-pass filter. Ideally the cut-off frequencies should coincide.

[*Tutorial note:* The pre-emphasis circuit is a differentiator while the de-emphasis circuit is an integrator. When a frequency modulated signal is differentiated it becomes phase modulated, and when a phase modulated signal is integrated it becomes frequency modulated.]

(*d*) The amplitude of the higher frequencies present in the frequency range of speech is small and can be eliminated by noise. A pre-emphases circuit increases the amplitude of these higher frequencies, improving their signal-to-noise ratio. The de-emphasis circuit restores these higher frequencies to their original amplitude and reduces the noise. Hence, pre- and de-emphasis improves the signal-to-noise ratio in a frequency-modulation communication system.

(*e*) Advantages:

(*i*) better audio reproduction, and
(*ii*) capture effect.

Disadvantages:

(*i*) wider bandwidth which results in less channels,
(*ii*) limited range of transmission when operated at very high frequencies.

*Q13* (*a*) *What information may be obtained from a field-strength diagram?*
(*b*) *For any* TWO *of the following aerials, Yagi, Log Periodic, Rhombic or Horn, give:*

(*i*) *principle of operation,*
(*ii*) *gain,*
(*iii*) *impedance, and*
(*iv*) *field-strength diagram.*

(*c*) *Why is the value of the impedance of an aerial important?*

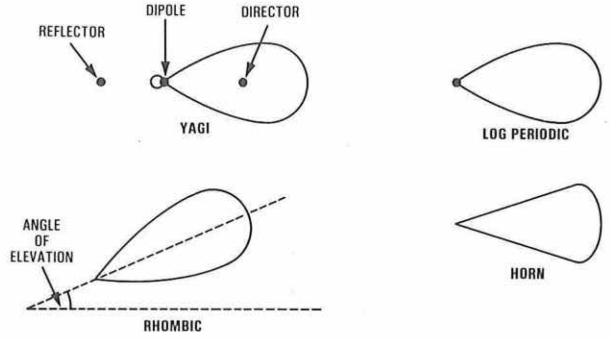
**A13** (*a*) The field strength diagram gives the signal-strength and directional properties of an aerial.

(*b*) (*i*) **Principle of Operation**
*Yagi* This aerial consists of an active element (for example dipole), one reflector and one or more directors. The reflector returns the signal to the active element so that it enhances signal strength. The directors, depending on the number used, have a capacitive effect upon the active element, and this gives the aerial its directivity.
*Log Periodic* The construction of this aerial enables one element to become active at its resonant frequency. The number of dipole lengths, the ratio of these lengths and the distance between the dipoles affect the scaling factor. The dipoles, other than the one acting as the active element, effect the direction away from the feeder. The log periodic provides a useful wide-band aerial in the ultra-high-frequency band.
*Rhombic* Travelling waves along 2 conductors which are not parallel radiate electromagnetic energy. The angle of radiation depends on the conductors forming a rhombus and the length of the sides of the rhombus. The height of the aerial from the ground affects the side angle. Although the impedance of the aerial is affected by the terminating impedance (there are no standing waves), spacing of the conductors within each limb of the rhombic aerial mainly determines the impedance.
*Horn* Power can be radiated from the open end of a waveguide. The pattern of radiation is very broad when the end of the waveguide is shaped by opening out the end into a horn shape. The horn is shaped according to the radiation pattern required.

(*ii*) **Gain**
*Yagi* 5–30 dB, depending upon the number of directors.
*Log Periodic* 10 dB.
*Rhombic* 5–15 dB, depending upon length of rhombus.
*Horn* 20–30 dB, depending upon dimensions.

(*iii*) **Impedance**
*Yagi* 73 Ω, depending upon the active element.
*Log Periodic* 300 Ω.
*Rhombic* 600 Ω.
*Horn* Depends upon the waveguide used.

(*iv*) **Field-Strength Diagram**

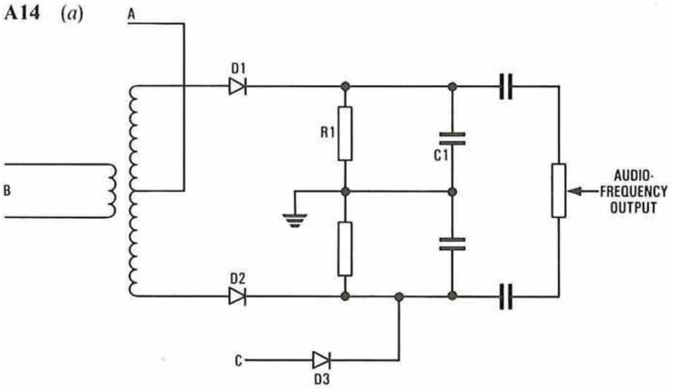


(*c*) Knowledge of the impedance of an aerial is important so that the aerial can be matched to enable maximum energy transfer and, therefore, the elimination of standing waves.

*Q14* (*a*) *Draw a circuit diagram for a demodulator capable of double-sideband* (*DSB*) *and single-sideband* (*SSB*) *detection.*
(*b*) *Explain the operation of the circuit when:*

(*i*) *the input is DSB, and*
(*ii*) *the input is SSB.*

**A14** (*a*)



(*b*) (*i*) The DSB signal is applied to input B and a positive voltage, to reverse bias diode D2, at input C. This reduces the circuit to a conventional demodulator where diode D1 eliminates the negative half cycle of the incoming signal. Resistor R1 and capacitor C1 filter out the unwanted components leaving the audio-frequency signal.
(*ii*) When the input signal at B is SSB, there is a negative bias voltage at input C which reverse biases diode D3. Also, a constant frequency is applied to input A. The value of the frequency depends on the intermediate frequency, but a typical frequency is 100 kHz. This re-inserted signal is modulated with the SSB signal, and an action similar to that of a balanced modulator is produced.

*Q15* (*a*) *With the aid of diagrams describe how long-distance radio communication is achieved at HF.*
(*b*) *Explain the following terms associated with propagation:*

(*i*) *critical frequency,*
(*ii*) *maximum usable frequency* (*MUF*), *and*
(*iii*) *optimum traffic frequency.*

*Q16* (*a*) *Define 'noise factor'.*
(*b*) *Discuss the significance of signal-to-noise ratio and noise factor in a radio receiver.*
(*c*) *What is meant by the term 'white noise'?*
(*d*) *How is white noise used to obtain the noise power ratio* (*NPR*) *in a communication system?*

*Answers contributed by P. Shenton*

# SCOTEC: DIGITAL TECHNIQUES AND TRANSMISSION 1983

**Students were expected to answer all the questions in section A and any 4 questions from section B**

## SECTION A

*Q1 State 4 performance factors to be considered when choosing an integrated circuit logic family.* *(4 marks)*

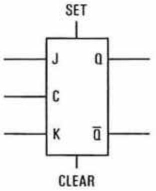
**A1** Any 4 of the following:

(*a*) switching speed,
(*b*) power dissipation,
(*c*) noise margin,
(*d*) circuit density, and
(*e*) fan-out.

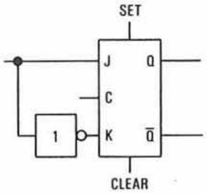
*Q2 Give the truth table and circuit symbol for a JK bistable. Show how it may be connected to form a D-type bistable.* *(6 marks)*

**A2**

| J | K | $Q_{n+1}$ |
|---|---|---|
| 0 | 0 | $Q_n$ |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | $\overline{Q_n}$ |



JK bistable



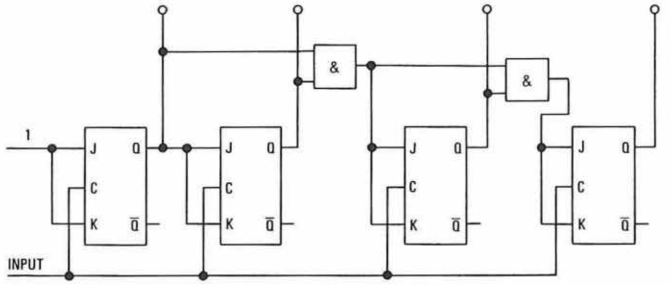
D-type bistable

*Q3 Explain the difference between combinational and sequential logic elements.* *(4 marks)*

**A3** Combinational logic elements have their outputs governed by the present inputs only. Sequential logic elements have their outputs determined not only by the present inputs, but also by the previous state of the circuit.

*Q4 With the aid of a diagram, show how a 4 bit pure-binary counter may be constructed from JK bistables.* *(5 marks)*

**A4**



[*Tutorial note:* A ripple-through counter would also have been acceptable.]

*Q5 Give reasons for the use of non-linear quantisation in preference to linear quantisation for speech encoding.* *(6 marks)*

**A5** Non-linear quantisation is used to improve the signal-to-noise ratio at low signal levels by reducing the difference between levels at low levels and widening the difference for higher-level signals. Thus, quantisation noise affects the small signals less, but the large signals more.

*Q6 Describe the principle function of a regenerator in a line transmission system.* *(4 marks)*

**A6** Regenerators are used to produce new pulses from the incoming pulses, which may be badly distorted but still recognisable. In this way, digital signals can be transmitted over very long line lengths with little or no distortion of the signal.

*Q7 Describe* THREE *types of information which are transmitted in addition to the message signal in a digital pulse train.* *(6 marks)*

**A7** Any 3 of the following:

(*a*) parity—additional bits included to allow error checking and correcting,
(*b*) synchronisation—the signals included to keep the receiver and sender is phase,
(*c*) alarm data—to initiate failure procedures if synchronisation fails etc, and
(*d*) signalling data—the routeing information for the data channels.

*Q8 State the reason for using constant-carrier working in a data network.* *(5 marks)*

**A8** Constant-carrier working is necessary to ensure correct phase reference between receiver and transmitter when phase-shift keying is being used.

[*Tutorial note:* This problem can be overcome by using differential phase-shift keying, where the phase of the previous digit is used as reference.]

*Q9 Describe quadrature amplitude modulation (QAM).* *(6 marks)*

**A9** Quadrature amplitude modulation (QAM) is a means of using a combination of phase and amplitude modulation to increase the number of bits sent at a time. If, in addition to the 4 phases used to give 2 bits at a time, the amplitude is allowed 2 possible values, there would be 8 possible states, giving 3 bits at a time.

*Q10 Describe the applications of a packet-switched network for data transmission.* *(4 marks)*

**A10** In the packet-switched network, the data (or messages) to be transmitted are broken down into fixed-length packets. If the message is large, then it would be broken into packets before transmission and re-assembled at the destination. Each packet is carried within control and error checking information envelopes. Because the passage of information can be much faster and time sharing is possible, many users can be served simultaneously. If necessary, the packets received are stored comparatively slowly in memory before they are transferred at a much higher speed along a suitable network highway to their destination.

## SECTION B

Each question in this section carried a total of 25 marks.

*Q11* (*a*) *Give the advantages and disadvantages of the use of integrated circuits (ICs) in electronic systems.*
(*b*) *Compare, by use of a table or otherwise, the relative performances of CMOS, TTL and ECL logic families.*

**A11** (*a*) The advantages are:

(*i*) cost, as they are generally cheap;
(*ii*) space and weight, as they are small and light;
(*iii*) standardisation is readily achieved;
(*iv*) ease of connection and replacement; and
(*v*) low power consumption.

The disadvantages are:

(*i*) the difficulty of servicing and localising faults without special equipment and diagrams,
(*ii*) faults are rectified by replacement instead of repair, and
(*iii*) the liability to damage from static electricity.

(*b*)

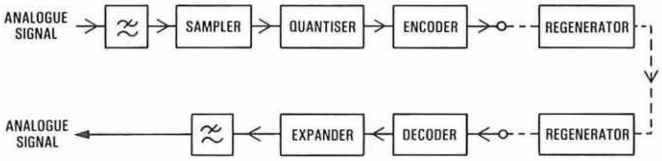
| Device Family | Power Supply | Fan-out | Power Dissipation | Noise Immunity | Delay |
|---|---|---|---|---|---|
| TTL | 5 V ± 10% | 10 | 12 mW | Very good | 10 ns |
| ECL | −5·2 V ± 10% | 25 | 25 mW | Fair | 2 ns |
| CMOS | 3–18 V | >50 | 0·01 mW | Very good | 60 ns |

*Q12* (*a*) *Explain, with the aid of a truth table and block diagram, the operation of a 4 bit shift register when offered serial input of 1100. (The first bit entered is 1.)*
(*b*) *Describe a typical use of this register.*

*Q13* (*a*) *Describe, using a labelled block diagram, the operation of a pulse-code modulation (PCM) system.*

(*b*) *State the minimum sampling rate for an analogue signal. Explain the need for this minimum rate.*

**A13** (*a*) In a pulse-code modulation system, the analogue signal is sampled at a fixed rate. The resulting samples are then compared with a set of levels and assigned discrete values. Because of slight differences between the original sample and the quantised signal, there is an error known as *quantisation noise* introduced. The quantised level of signal is now coded in binary form for transmission. If necessary, regenerators renew the pulses along the way. At the receiving end the process is reversed, and the bits making up the sequence are decoded by a digital-to-analogue converter to reproduce the analogue signal. A block diagram of a typical system is shown in the sketch.



(*b*) The minimum sampling rate for the analogue signal is twice the highest frequency present in the signal. At this sampling rate or higher the original signal can be reconstructed with little distortion.

*Q14* (*a*) (*i*) *Draw the time-slot/frame diagram for a 30-channel time-division multiplex (TDM) system.*

(*ii*) *Describe the signal carried in each time-slot.*

(*b*) *Calculate the gross bit rate for a channel bandwidth of 4 kHz.*

*Q15* (*a*) *Explain the following with reference to data transmission.*

(*i*) *group delay,*
(*ii*) *phase jitter,*
(*iii*) *crosstalk, and*
(*iv*) *impulse noise.*

(*b*) *Describe an error checking technique that can be used to monitor a digital pulse chain.*

**A15** (*a*) (*i*) Group delay is caused by frequency components of a given signal being transmitted at different speeds; therefore, the phase relationships at the receiver are different from those at the transmitter. This causes distortion which may not affect speech signals too much, but which can severely affect data signals, where shape is important.

(*ii*) Phase jitter distorts data because of the variations of phase in regenerators, which may not be exactly synchronised. This can happen because of mistuning in the regenerator tank circuit, noise on the received waveform and limitations of equalisation. Phase jitter is the main form of cumulative distortion in a digital network.

(*iii*) Crosstalk arises because of adjacent channels operating at similar frequencies as the wanted signal. However, it decreases as the bandwidth increases. Square waves (pulses) are distorted because of the finite bandwidth.

(*iv*) Impulse noise is caused by lightning, switching etc. It is a common form of noise and can affect digital signals because of their pulse nature.

(*b*) To check for errors, some form of redundancy is added to the data so that an error can be detected. If an error is detected, re-transmission is requested automatically. The extra bits are known as *parity bits* and result in odd or even parity, as required; that is, odd or even numbers of 1s in the word transmitted, as shown in the following table.

| Parity | Parity Bit | Data |
|---|---|---|
| Odd | 1 | 0 1 0 1 0 1 1 |
| Even | 0 | 0 1 0 1 0 1 1 |

[*Tutorial note:* An explanation of any suitable method of parity checking, or redundancy checking would have been acceptable; for example, forward error control.]

*Q16* (*a*) *With reference to a data terminal, describe the features of*

(*i*) *the main-frame processor,*
(*ii*) *the front-end processor.*

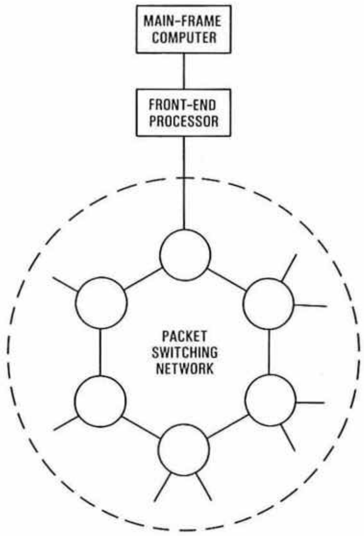
(*b*) *Give a block diagram showing the above connected to a data network.*

(*c*) *Describe intelligent and non-intelligent data terminals.*

**A16** (*a*) (*i*) The main-frame processor is a high-powered computer with a large memory and a very-high-speed data handling rate. It is a multi-terminal device and gives software support for the front-end processors.

(*ii*) The front-end processor is a separate processor to deal with the data communication links, which would be a heavy load on the main-frame computer. A front-end processor might undertake such tasks as polling, error detection and correction, the main task of the main-frame computer being to supply the messages and deal with interceptions.

(*b*)



(*c*) An intelligent terminal is a device that can be programmed to manipulate data sent to and received from the main processor. A non-intelligent terminal is a device for the input and output of data through a communication system, but is unable to perform the necessary functions to act as a packet terminal.

*Answers contributed by J. W. Baird.*

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Published by *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG
and printed in Great Britain by Unwin Brothers Limited, Old Woking, Surrey.